

Using System Dynamics Computer Modeling Software to Teach Cause-Effect Relationships in Reading Selections

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Abstract: The purpose of this study was to determine if the use of system dynamics computer modeling software would affect student ability to recognize cause-effect relationships in reading selections. Pre- and posttests were administered to measure changes in reading comprehension and a pre- and post-intervention Likert Scale survey was administered to determine changes in student attitudes relating to the use of computer software in reading instruction. A performance rubric was also used to gauge progress specifically related to using system dynamics computer modeling techniques for identifying cause-effect relationships in reading selections. The setting was an inner city gifted center and the participants were fourth and fifth-graders who attend the center one day per week. System dynamics strategies were used to examine reading selections and, as the culminating activity, STELLA™ computer modeling software was used to model diagrams of the causal relationships within stories. Because of the one-group pretest-posttest design, no conclusive results could be obtained, however, it was concluded, based on observations and data, that the ability of students to recognize cause-effect relationships in selected readings improved as a result of the intervention.

Introduction

Context of the Problem

I became interested in how children learn to identify cause-effect relationships in reading selections after observing a Four Blocks reading lesson at the school where my gifted education center is located. The Four Blocks is a method of teaching reading in the primary grades that is “designed to meet the needs of children with a wide range of entering literacy levels without putting them into ability groups” (Cunningham, 1999, p. 73). The purpose of my visit to the primary classroom was to garner ideas for a language arts unit to use as part of the gifted curriculum. I was particularly interested in the guided reading block, as it was my intention to introduce gifted children to various aspects of literature using small-group, partner, individual, and read-aloud formats.

After the reading was completed, the whole class was called together to discuss the selection. The teacher asked questions and the students responded. I observed that questions beginning with “Why” were the most difficult for the children to answer. Usually, the children’s responses were appropriate only after repeated prompting by the teacher. This was the case, even after rereading. The students’ ability to identify cause-effect relationships was still inconsistent after two or three readings of the same selection.

Later in the week I observed a reading lesson in a fourth grade classroom. Even though the instructional strategy was different than the Four Blocks method (Direct Instruction), the results approximated the earlier observation. The children were learning phonics, vocabulary, spelling, and other important skills, but comprehension, especially in the area of identifying cause-effect relationships, seemed to be lacking.

Based on the classroom observations and a perfunctory examination of reading comprehension scores, I decided to look more deeply into how reading comprehension is being taught in order to determine if another method might yield some improvement in this area—especially in the ability of students to identify cause-effect relationships in selected readings.

The traditional method of addressing cause-effect relationships is given by Taylor (1992): “A cause/effect text pattern consists of a description of events followed by a discussion of either what caused these events or what happened as a result of these events” (p. 221). In her discussion of story structure and traditional questions in reading instruction, Taylor states that questions elicit literal, inferential, and critical responses from the children following the reading, or hearing, of a story.

I found this description to be consistent with what I had observed in the classrooms I visited. Suspecting that there might be a developmental issue affected by this practice, I discovered that, according to Piaget and Inhelder (2000), it is unlikely that most preoperational and concrete operational stage children are capable of applying their reasoning skills to purely verbal problems. The child in the period of concrete operations is capable of

forming mental logical structures, but “these structures are weak and permit only step-by-step reasoning, for lack of generalized combinations” (p. 100). This led to the unearthing of an interesting research project by Kordigel (2000) that provided a link between my questioning the methods used to teach cause-effect relationships, and strategy used in this action research.

Kordigel’s research focused on the developmental issues involved in the teaching of cause-effect relationships to children. Using fairy tales as the selected readings, Kordigel discovered that children in the preoperational and operational stages of development are generally only able to concentrate on the event taking place at the moment. “All that had happened before that and what still might happen afterwards (thus the cause and effect) are of no interest to him, nor could they be, since the exceptionality and the intriguing nature of the ‘present’ event completely occupies him, mentally, as well as emotionally” (p. 7). This squared with what I had observed in the classroom. When asked to connect an event with a cause, invariably the children would resort to the most recent section or paragraph of the story that had been read. So, it seemed that the problem was that primary and elementary age children in general have a problem seeing the “big picture.” They link things together like a chain, with each effect being linked to a cause that has recently occurred in the reading. I asked the question, “What strategy, or method of teaching cause-effect relationships, might address this problem and improve children’s ability to recognize cause-effect relationships in selected readings?” Barry Richmond (2001) supplied the key. In his work on systems thinking (in this article, systems thinking and system dynamics are used interchangeably), Richmond describes the problem of identifying cause-effect relationships as, not only a developmental issue, but a cultural phenomenon as well.

Among the most sacred of all the covenants that bind members of a society together is the implicit agreement about how such relationships work. In Western cultures, the implicit agreement is that reality works via a structure of serial cause-and-effect relationships. Thus-and-such happens, which leads this-and-such to occur, and so forth. (p. 17)

Richmond explains this serialization of cause-effect relationships is derived from the assumptions that (a) the causal factors each operate *independently* on the effect or *dependent* variable; (b) causality runs one-way; (c) causal impacts are linear; and (d) causal impacts are instantaneous. These assumptions were reflected in the students’ answers to the “Why” questions asked by their teachers following readings. Inevitably, students would chain events together and select the most recent occurrence as the cause of an event.

Richmond (2001) believes there is a solution to linear, instantaneous thinking regarding causality. He advises the use of a skill he labels as “10,000 Meter Thinking” (p. 11-12). This concept was inspired by the view from a jet airliner at 10,000 meters. From such an altitude one sees very little vertical detail but gains a “big picture” perspective. Closely related to this is a skill that is called “Dynamic thinking” (p. 13). This thinking encourages individuals to “push back” from events and points in order to see a pattern of which they are a part. These are system dynamics strategies which, through the use of associated concrete diagrams and computer modeling, seem to offer the solution to teaching preoperational and concrete operational children the skill of identifying cause-effect relationships in reading selections. As I delved further into this matter, I found that Sweeney (2001) had created research based strategies for using system dynamics concepts in the elementary classroom in association with reading selections. Her methods allow students to explore beyond the immediate relationships in the story. Using what system thinkers have termed *system archetypes*, the author provides concrete strategies such as *feedback loops* to help children “understand how one event can influence another—even if the second event occurs a long time after the first, and ‘far away’ from the first” (p. 20).

After looking at the lessons which she developed, I made the determination that system dynamics offered the teaching method for which I was looking. Not only did it offer a method of thinking that would be compatible with elementary age children, but also provided the possibility of using computer modeling software called STELLA™ to test models of causal relationships developed by the students.

Statement of the Problem

A research study evolved that had as its purpose the exploration of using system dynamics instruction and computer modeling software to improve students’ ability to identify cause-effect relationships in reading selections. The independent variable was the use of system dynamics computer modeling software that allowed students to insert, examine, and test interconnections within a system, which, in this case, were reading selections. Reading selections are defined as teacher-selected readings from a variety of genre that are appropriate for the age and grade-level of the students.

The dependent variable was student ability to recognize cause-effect relationships in reading selections as measured by student scores on the cause-effect components of a reading comprehension test.

Research Questions

1. Will the use of system dynamics computer modeling software affect the ability of students to recognize cause-effect relationships in reading selections?
2. Will the use of system dynamics computer modeling software affect student attitudes toward the use of computers in reading instruction?
3. Can students apply system dynamics computer modeling techniques to the identification of cause-effect relationships in reading selections?
4. Will cause-effect recognition skills acquired through using system dynamics computer modeling software techniques improve performance in other areas of reading comprehension?

Method

Participants

The gifted center for which I am the resource teacher serves four schools, K-5, including the host school where the center is located. The center serves about 80 students. They are bused from their home schools and spend one full day at the center. Each grade level comes on a particular day. The host school is an inner-city school, as are all but one of the other schools served by the center. The children are identified as gifted according to state criteria that includes achievement and mental abilities scores, as well as creativity and motivation. I have the freedom to develop a curriculum for these students that fits within fairly broad guidelines. Reading is an important part of this curriculum and, combined with the fact that we have daily access to a computer lab, the gifted center was an ideal setting for the action research described in this article.

I determined that fourth and fifth-graders would participate in the project. This decision was based on the computer skills already possessed by the students and their age (9-10 year-olds), which falls within the developmental period of concrete operations. There were 13 fifth-graders and 14 fourth-graders who participated in the project.

Intervention

The intervention consisted of introducing children to system dynamics techniques in the manner suggested by Sweeney and Meadows (1995). Using activities designed to lead children into systems thinking, this material laid the foundation for the readings contained in *When a Butterfly Sneezes* (Sweeney 2001), a collection of lessons on applying system dynamics techniques to the reading of specific stories. At this point (four weeks into the intervention) the children were familiar with the language of system dynamics. Stories were now read and analyzed using strategies such as behavior-over-time graphs and causal loops. During this three-week period, students practiced analyzing stories including *The Wartville Wizard* (Madden, 1993), *The Butter Battle Book* (Seuss, 1984), *The Sneeches and Other Stories* (Seuss, 1989) and *Because a Little Bug Went Ka-choo!* (Stone, 1975). Children were then introduced to the STELLA™ system dynamics computer modeling software. Diagramming models of stories using stock/flow diagrams, which could later be tested using STELLA™, was accomplished through the use of activities found in *Getting Started* (Curry, 1995) and *Beginner Modeling Exercises* (Martin, 1997). After two weeks of constructing stock/flow diagram models, and observing demonstrations on a large screen monitor, the students were ready to begin designing and running their own models.

The story of Hamlet (Nesbit, 1997) was used as the reading selection for this phase of the intervention. The session began with an overview of the play. It was established that a central theme of the reading would be hamlet's need for revenge. Students were given a blank Behavior-Over-Time-Graph and asked to plot the increase and decrease of Hamlet's need for revenge as the story progressed. At each plotted point, students recorded the cause for the change. After the oral reading of the story, the graphs were explained and compared. They were fairly uniform. A typical finished graph displayed an up and down pattern as events transpired, and as Hamlet is presented with new evidence about his father's death. Using a diagram of a blank STELLA™ screen, students were asked to translate the graph into a stock/flow map. Hamlet's need for revenge was used as the stock. The increase and decrease was controlled by Hamlet's inclination to believe or disbelieve the evidence about his father's murder. The map was completed, as shown in Figure 1, and the model was tested using the software. The data that was manipulated depicted the frequency of Hamlet's believing the evidence to his doubting the evidence. Various "what-if" situations were tested. All pointed to an increasing need for revenge, fed by his belief of the evidence, until his father's death was avenged.

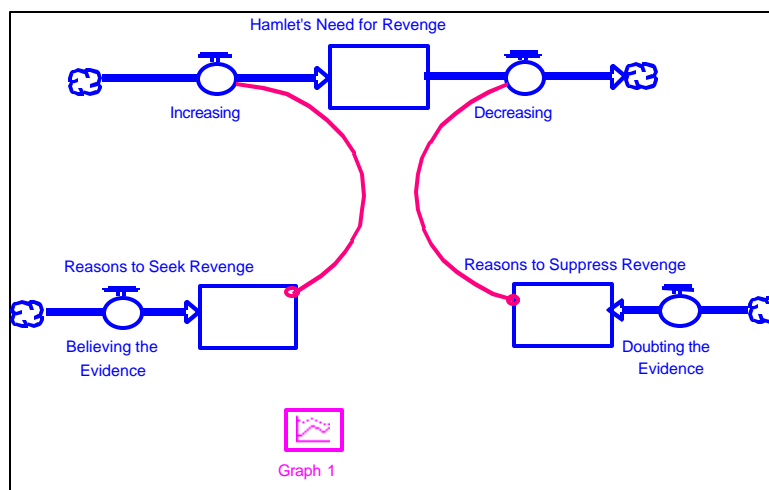


Figure 1: Stock/Flow Diagram for Hamlet as it appeared on the students' STELLA screen.

It was obvious that the students were aware of the causal relationships within the story that led to the killing of Claudius and the final revenge on behalf of his father. This unsophisticated computer modeling exercise generated discussion and insight into the story that I have seldom experienced by simply reading and asking questions following a story.

Measures

A one-group pretest-posttest research design was used to measure the effect of the intervention on the dependent variables. The use of system dynamics computer modeling software and its effect on student ability to recognize cause-effect relationships in reading selections (Research Question 1) was measured using reading comprehension pre- and posttests developed by Pesiri and Hart (1991). Two scores were derived from the tests—an overall comprehension score and a cause-effect relationship score. The fourth and fifth-grade classes were pretested, the experimental treatment was administered, and then the classes were posttested. The paradigm for this design was Pretest → Treatment → Posttest. The means were compared using a Paired Samples *t* test in order to evaluate the influence of the treatment variable. Paired samples *t* tests determine whether or not two scores are significantly different from each other. Although this design can produce no conclusive results (Leedy, 1997, p. 232), the results might be useful for a formative assessment of the intervention as well as a foundation for further research.

The effect of system dynamics computer modeling software on student attitudes toward the use of computers in reading instruction (Research Question 2) was measured using a Likert Scale Survey. The modes of the pre- and post-intervention Likert Scale instruments were derived and compared.

Student ability to apply system dynamics computer modeling techniques to the identification of cause-effect relationships in reading selections (Research Question 3) was assessed through the use of a performance rubric. The rubric was used to measure the progress of each student. Points ranged from 1 (novice) to 4 (expert). A profile of individual performance resulted from the rubric. Frequencies and percentages were calculated for each item on the rubric.

The transfer of cause-effect identification skills to other areas of reading comprehension (Research Question 4) was measured by comparing the pre- and posttest results on the comprehension test. The means were compared using a Paired Samples *t* test in order to evaluate the influence of the treatment variable.

Procedures

The students used in the project were previously assigned to classes based on their qualification for the gifted program and grade level. The sizes of the groups of fourth and fifth-graders were 13 and 12 respectively. At the beginning of the intervention period the unit of study was explained to the students. They were told specifically that it was hoped that their ability to recognize cause-effect relationships would be enhanced and that this would result in doing well on reading comprehension tests. The data was collected by me and analyzed using SPSS™ Base 10.0 (SPSS, 2000).

The reading comprehension test (Pesiri & Hart, 1991) featured a set of instructions that were read to the students prior to beginning the test. I also explained that the results of the test would not affect their grade or standing in the gifted program. A separate answer sheet for marking the test was provided. The time allowed for the

test was twenty minutes. Different tests were administered to the fourth and fifth-graders, due to the differences in reading levels. The pre- and posttests contained different material, but the same number of questions. The answer sheets were scored using the answer key section of the teacher's guide.

The Likert Survey was administered on the first and last days of the intervention. Students were informed that its purpose was to determine if there was a difference in their opinion or attitude about reading, finding cause-effect relationships, and using computer software to increase reading skills, before and after the weeks of instruction. Also, it was made clear that the survey would in no way affect their grade or standing in the gifted program. They were given enough time to answer all questions on the survey. Each student's performance rubric was updated during the course of the instruction. Each item was explained to the students prior to the intervention. As the rubrics were scored, the results were shared with each student. The products that were created by the students were matched with the items on the rubric in order to derive the score.

Results

The cause-effect and total comprehension pre- and posttest results for the fourth and fifth grades (research questions 1 and 4) were analyzed using a paired samples *t* test which compares the means of two scores from related samples, which in this case consisted of the pre- and posttest scores for each group. Paired samples *t* tests, according to Cronk (1999) determine whether or not two scores are significantly different from each other. Significant values indicate the two scores are different. Values that are not significant indicate the scores are not significantly different.

The fourth grade mean on the cause-effect portion of the pretest was 72.92 (*sd* = 24.91) and the mean on the posttest was 95.83 (*sd* = 9.73). A significant increase from pretest to posttest was found. A *t* of -3.188 was obtained, with 11 degrees of freedom and a significance level of less than .01.

The fifth grade mean on the cause-effect portion of the pretest was 86.54 (*sd* = 16.51) and the mean on the posttest was 90.38 (*sd* = 12.66). No significant difference from pretest to posttest was found. A *t* of -.693 was obtained, with 12 degrees of freedom and a significance level of .50. A significance level greater than .05 on a two-tailed test indicates that the result is not significant.

Combining the scores for both groups on the cause-effect portion of the comprehension test yielded a pretest mean of 80.00 (*sd* = 21.65) and a posttest mean 93.00 (*sd* = 11.46). A significant increase from pretest to posttest was found. A *t* of -2.701 was obtained, with 24 degrees of freedom and a significance level of less than .02.

The fourth grade mean on the total comprehension portion of the pretest was 52.08 (*sd* = 14.21) and the mean on the posttest was 80.83 (*sd* = 9.73). A significant increase from pretest to posttest was found. A *t* of -7.772 was obtained, with 11 degrees of freedom and a significance level of less than .001.

The fifth grade mean on the total comprehension portion of the pretest was 72.31 (*sd* = 12.59) and the mean on the posttest was 76.62 (*sd* = 9.78). No significant difference from pretest to posttest was found. A *t* of -1.326 was obtained, with 12 degrees of freedom and a significance level of .21.

Combining the scores for both groups on the total comprehension portion of the comprehension test yielded a pretest mean of 62.60 (*sd* = 16.68) and a posttest mean 78.64 (*sd* = 9.79). A significant increase from pretest to posttest was found. A *t* of -4.636 was obtained, with 24 degrees of freedom and a significance level of less than .001.

The Likert Scale survey, used to measure changes in the students' attitudes about the use of computer software in reading instruction as a result of using the computer modeling software (research question 2), was analyzed using only those questions that pertained to the research question (questions 4, 7, and 10). The following graphs compare the modes on the pre- and post-intervention surveys.

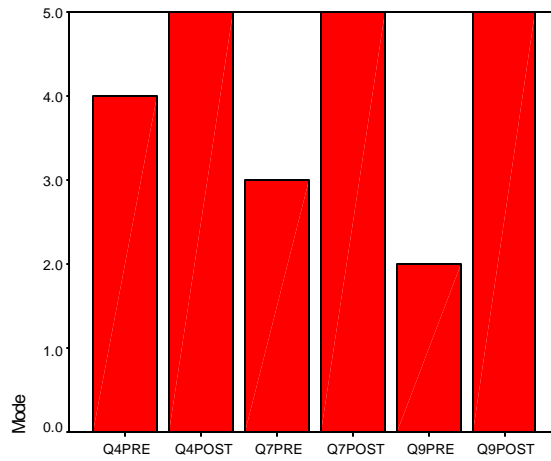


Figure 2: Fourth grade pre- and post-intervention Likert Scale survey.

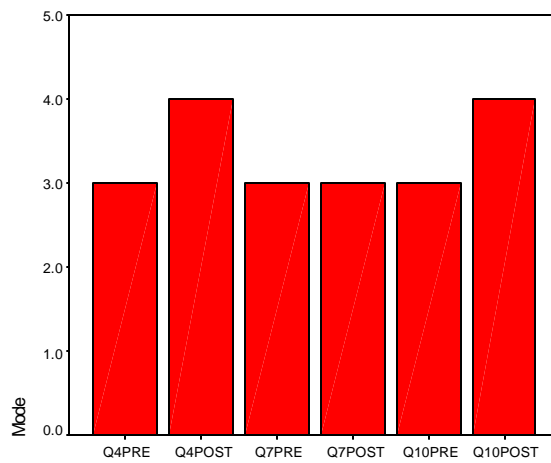


Figure 3: Fifth grade pre- and post-intervention Likert Scale survey.

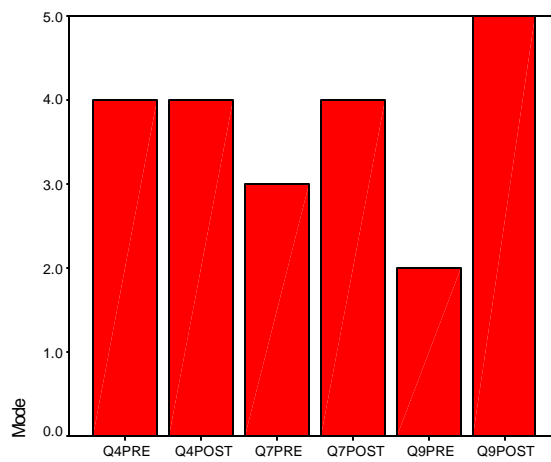


Figure 4: Fourth and fifth grade combined pre- and post-intervention Likert Scale survey.

The performance rubric, used to evaluate student ability to apply system dynamics computer modeling techniques to the identification of cause-effect relationships in reading selections (Research Question 3), was analyzed in terms of the frequency and percent of scores for each of the three objectives, which were (a) identifies cause-effect relationships using system dynamics techniques; (b) uses stock/flow diagrams to design a system dynamics model of cause-effect relationships in selected readings; and (c) tests a system dynamics model of cause-effect relationships in selected readings using STELLA™ computer modeling software. Performance was rated as 1 (novice), 2 (apprentice), 3 (proficient), or 4 (expert). Table 1 displays the results.

Level of proficiency	Fourth Grade						Fifth Grade					
	Frequency			Percent			Frequency			Percent		
	2	3	4	2	3	4	2	3	4	2	3	4
Objective 1	1	1	12	7.1	7.1	85.7	0	5	8	0	38.5	61.5
Objective 2	1	1	12	7.1	7.1	85.7	1	6	6	7.7	46.2	46.2
Objective 3	1	6	7	7.1	42.9	50.0	0	8	5	0	61.5	38.5

Table 1: Results of Performance Rubric

Discussion

The purpose of this study was to determine if the use of system dynamics computer modeling software would affect student ability to recognize cause-effect relationships in reading selections.

The first research question associated with this purpose was to determine if the use of system dynamics computer modeling software would affect student ability to recognize cause-effect relationships in reading selections. The fourteen fourth grade students showed a significant increase from the pretest to the posttest on the cause-effect questions of the reading comprehension test. The thirteen fifth grade students showed no significant difference between the pretest and posttest. The mean score did, however, increase from 86.54 to 90.38. The combined scores from both groups increased significantly from a mean of 80.00 to 93.00. Because this was a one-group pretest-posttest design, no conclusive results can be drawn from the data analysis. However, the significant gains by the fourth grade students, and the overall significant increase in the means of both groups, combined with observations and feedback from students, provided a strong indication that the students' ability in this area increased during the course of the intervention.

It would be difficult to conclude that the computer modeling experience solely accounted for the improvement. All of the system dynamics activities, readalouds, behavior-over-time graphs, causal loops, and story mapping, played a role in the increased ability of students to recognize cause-effect relationships in selected readings. Since the computer modeling activity was the culminating activity of the intervention, and all other activities served as prerequisites to that experience, I would suggest that it did play an important role in the learning that occurred.

The second research question examined student attitudes toward the use of computers in reading instruction as a result of using system dynamics computer modeling software. The results of the Likert Scale survey were analyzed by comparing the modes of the pertinent questions (4, 7, and 10). The survey was scaled from 1 (strongly disagree) to 5 (strongly agree).

On question 4 (I think a computer program could improve my reading skills.), the fourth grade students pretest mode of 4 increased to 5 on the posttest. Question 7 (I like computer programs that can help me do better on reading tests.) jumped from 3 to 5. Question 10 (I like using a computer program to help me better understand the stories I read.) increased from a pretest mode of 2 to 5 on the posttest.

The fifth grade students showed a modal increase from 3 to 4 on question 4, while question 7 remained static at 3 on the pre- and posttest. Question 10 increased from 3 to 4.

When the results of the fourth and fifth grade students were combined, question 4 showed a mode of 4 on the pre- and posttest; question 7 increased from 3 to 4; and question 10 went from a mode of 2 all the way up to 5.

The largest increase in attitudes regarding using computer software in reading instruction was question 10. The fourth-graders increased from 2 (disagree) to 5 (strongly agree) on this one while the fifth-graders climbed one level, from 3 to 4. Based on my experience with these groups I know that the fifth-graders had a little more prior experience using computer software in connection with reading activities than the fourth-graders. This could account for the initial disparity between the fourth and fifth-graders' response to the question. This could also explain the fact that the fifth grade students didn't show the marked positive change in attitudes exhibited by the fourth grade results. Having had more experience with computer programs and reading instruction, their attitudes about computers were probably partially "jelled" before the intervention began. I draw a positive conclusion from these results. Considering the newness of the strategies and the fairly complex nature of STELLA™, any increase in student attitudes would indicate that the intervention enjoyed some success.

The third research question addressed the ability of students to apply system dynamics computer modeling techniques to the identification of cause-effect relationships in reading selections. A performance rubric was used to measure progress in three areas related to this question: (a) Identifies cause-effect relationships using system dynamics techniques; (b) Uses stock/flow diagrams to design a system dynamics model of cause-effect relationships in selected readings; and (c) Tests a system dynamics model of cause-effect relationships in selected readings using STELLA™ computer modeling software. Performance was rated from 1 (novice) to 4 (expert).

On objective 1, the fourth grade students scored 85.7% in the expert range. On objective 2 it was 85.7% experts, but on objective 3 only 50% of the students achieved expert. 42.9% of the students were in the proficient range.

Among fifth-graders, objective 3 also showed a diminished number scoring in the expert column. The majority (61.5%) were scored as proficient. Overall, the majority of the students were scored as experts on objectives 1 and 2. On objective 3, the majority were deemed proficient.

The performance rubric scores indicated that students were able to apply system dynamics computer modeling techniques to the identification of cause-effect relationships in reading selections. The fact that many were not able to design and run complex models using STELLA™ can be accounted for by the fact that more time was not allotted to developing computer modeling skills. The majority of the intervention time was used developing skills to facilitate objectives 1 and 2 which were prerequisite to using the computer modeling software to analyze relationships in stories.

The fourth research question examined transferring cause-effect recognitions skills, acquired through the use of systems dynamics computer modeling software techniques, to other areas of reading comprehension. The fourth grade showed a significant increase from pretest to posttest, but no significant difference was found among the fifth-graders. When the groups were combined, the overall increase in the means from 62.60 to 78.64 was found to be significant. Even though no statistical meaning can be associated with these results, an overall increase in comprehension skills as a result of understanding cause-effect relationships within reading selections is indicated.

Although the focus of this action research plan was the use of computer modeling software to help students identify cause-effect relationships in selected readings, it should be noted that the use of system dynamics techniques prior to the experience in the computer lab played a large role in the intervention. Students were observed viewing stories from the "10,000 meter" perspective by the time they completed one or two behavior-over-time graphs. It is possible that positive results could have been achieved through the use of the systems dynamics strategies alone. The computer modeling experience, however, did provide an incentive for the students to participate and do well through the entire instructional period. They were told in the beginning that the culminating activity of the unit would be to test their ideas about cause-effect relationships in stories using the computer software.

The selected readings also played a positive role in the outcome of the intervention. All of the stories were selected specifically because their content featured obvious causal relationships. Dr. Seuss' (1984) *The Butter Battle Book* is a prime example. After the reading and construction of a causal loop, the students discussed the idea of the escalation structure of weapons races for a full hour.

In view of the fact that this was a one-group pretest-posttest design, and did not employ the use of a random sample, at the very best, this project might serve as a precursor to further research. At the very least, it has given this instructor new tools for the teaching of reading and a fourth and fifth grade class of gifted students a richer experience in the area of reading.

The results of this action research were communicated to curriculum specialists, team leaders, and teachers within my organization through an online PowerPoint presentation at our school web site. The unit will become a regular component of the fourth and fifth grade gifted education curriculum at my gifted center. It will be expanded to include more readings, and more time for working on the computer modeling software will be allotted to students than was made available during the course of the current project.

This study has shown that system dynamics and computer modeling software can play an important role in the teaching of reading, especially in the area of comprehension and cause-effect relationships. Also, implied by this study is the fact that computer modeling software can have a positive impact on the attitudes of students about reading instruction. It is also readily apparent that, although computer modeling software is very complex and sophisticated, it can be understood and used on an elementary level by young children. Finally, regarding reading comprehension scores, I think it is implied by this study that enhancing the ability of students to understand cause-effect relationships in reading will improve their overall performance in reading comprehension.

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